CA0479#2

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Fuel Cell Operation on ADG

U.S. EPA Fuel Cell Workshop

June 26,2001

International Fuel Cells
A United Technologies Company

International Fuel Cells
195 Governor's Highway
South Windsor, Connecticut 06074 USA
(860) 727-2200
www.ifc.com

IFC CORPORATE STRUCTURE

United Technologies Corporation

Research Center

UT Power Solutions

Pratt & Whitney Power Systems

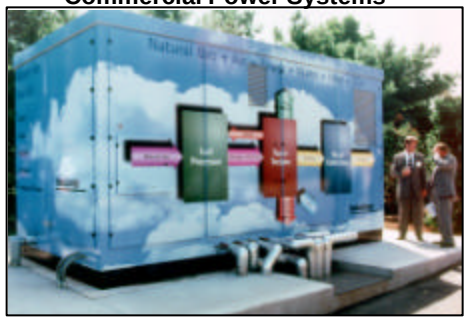
International Fuel Cells
A United Technologies Company

Pratt & Whitney Canada MicroTurbine

Space & Defense

CA0815

Commercial Power Systems



WCN15802

Residential

CA0498

Transportation

CA0691

CA0493A

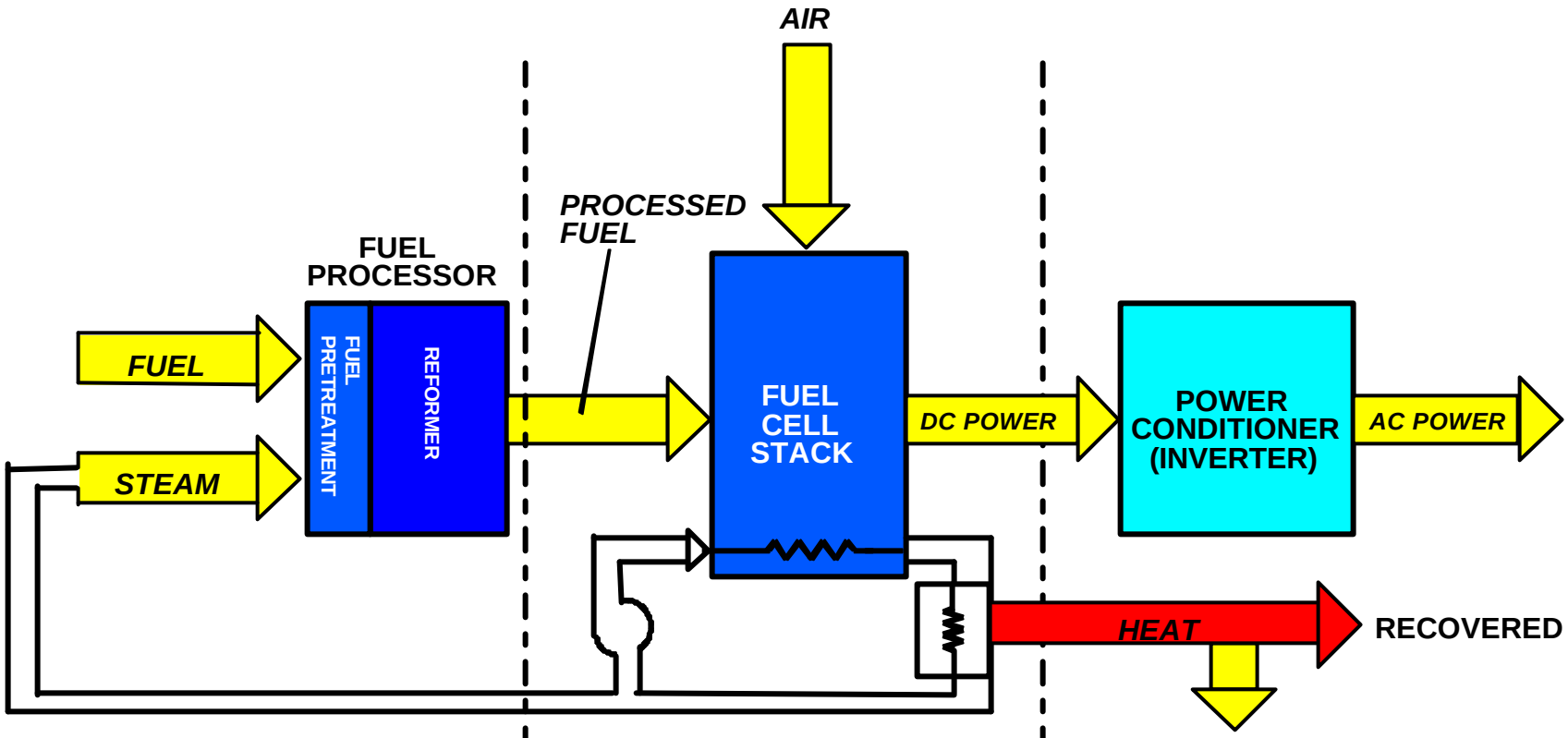
PPT01517
R010606

FUEL CELL TECHNOLOGIES

	Fuel Cell Type	Applications	Operating Temperature ºC	Comments
	Alkaline	Space	80 - 100	Needs pure fuel/oxidant
	Phosphoric Acid	Stationary	200 - 220	Long life Useful heat
	Proton Exchange Membrane	Stationary Transportation	80 - 100	Short start time, Easily manufactured Small size / scalability Limited co-gen
	Molten Carbonate	Stationary	600 - 650	High efficiency Good co-gen Difficult to manufacture
	Solid Oxide	Stationary	650 - 1000	High efficiency Exotic materials Good co-gen

PPT00802
R012504

SIMPLIFIED FUEL CELL SYSTEM



Processes natural gas fuel for fuel cell use

$CH_4 + 2H_2O \quad 4H_2 + CO_2$

Converts hydrogen and air into DC power

$H_2 \rightarrow 2H^+ + 2e^-$

$1/2\ O_2 + 2H^+ + 2e^- \rightarrow H_2O$

Converts DC power to usable AC power

PPT-01170
010702

IFC FUEL CELL MARKETS

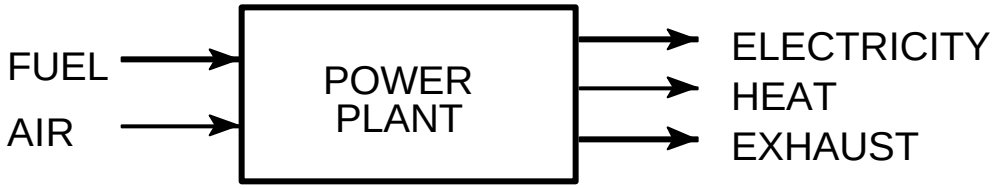
PC25™ operating fleet

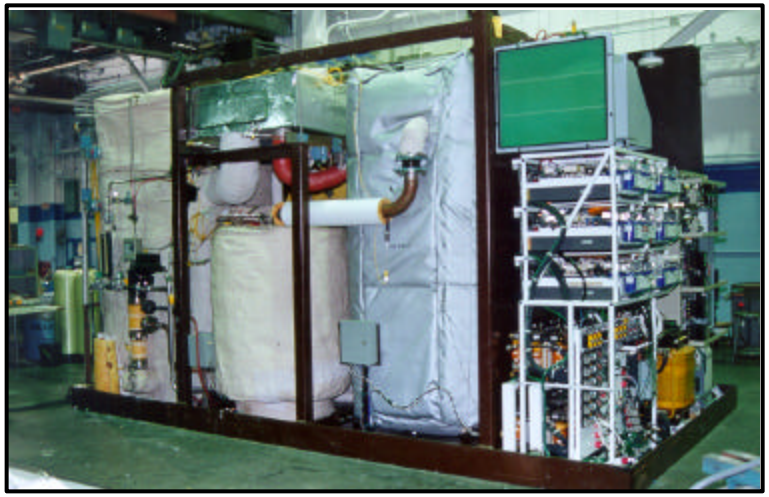
WCN-15162

200 KW NATURAL GAS POWER PLANT

Number of units delivered	**225**
- Fleet hours	**over 4 million hours total**
- Longest Continuous Operation	**9,506 hours**

COMPLETE FUEL CELL POWER PLANT

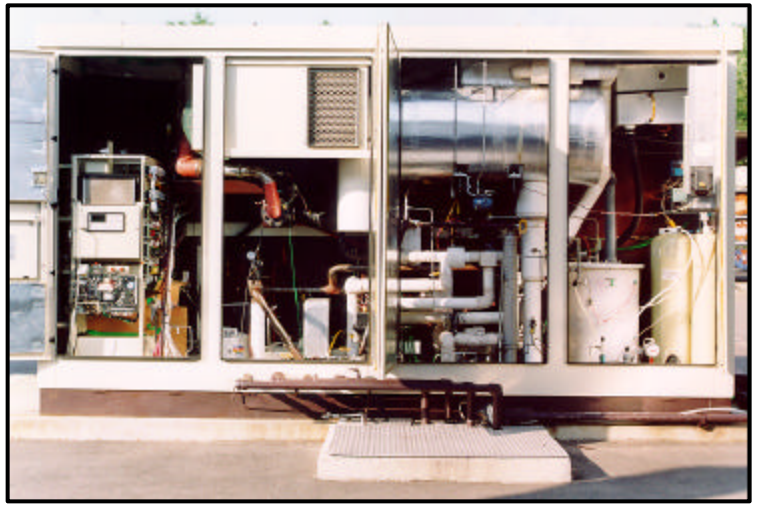




810f13C

Major Components

- Fuel Processor
- Cell Stack
- Power Conditioner



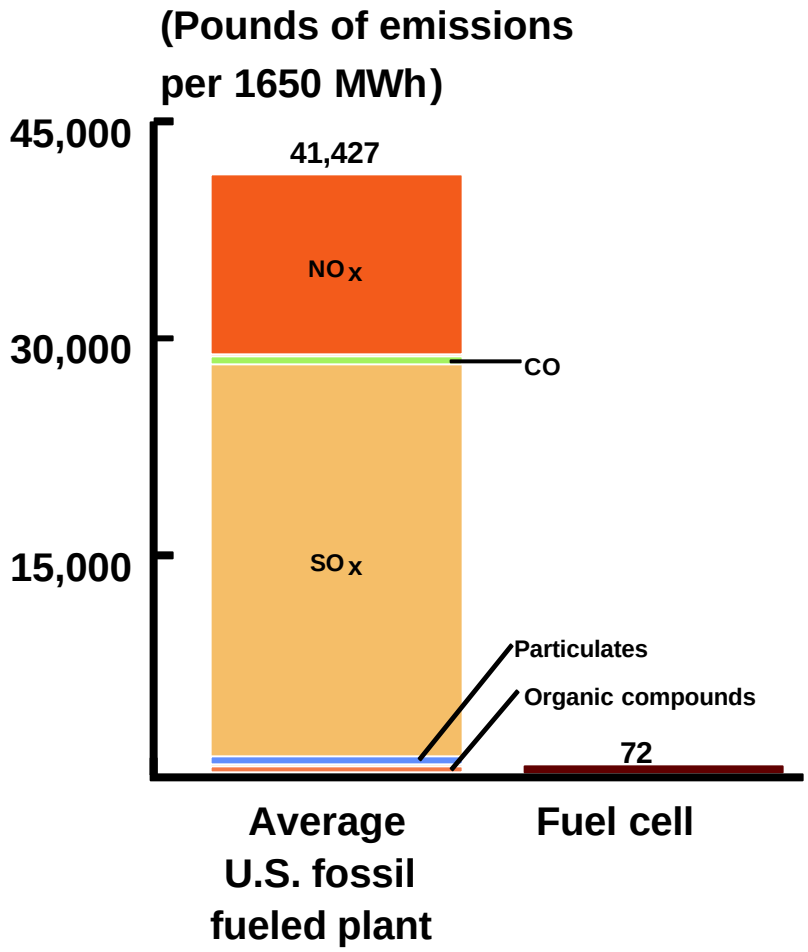
WCN15165

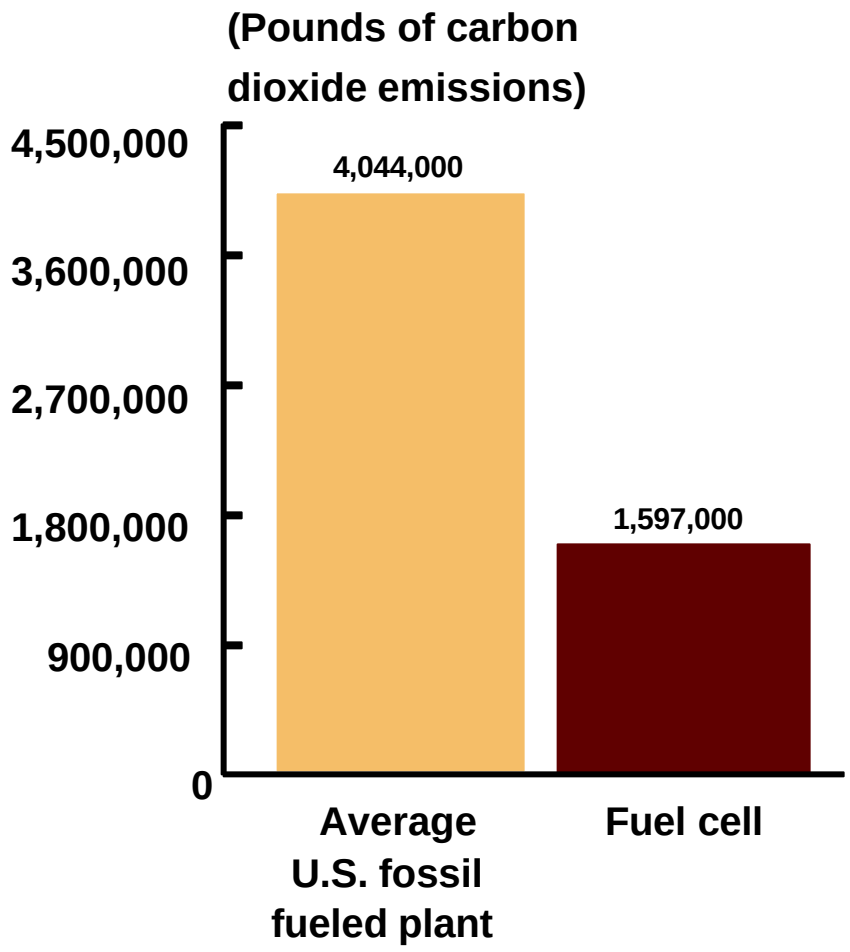
Ancillary Systems

- Fuel and Air Supply
- Heat and Water Management
- Ventilation
- Control, Diagnostics

FUEL CELL AIR EMISSIONS

PC25 emissions from one year of operation vs. average U.S. fossil fuel plant





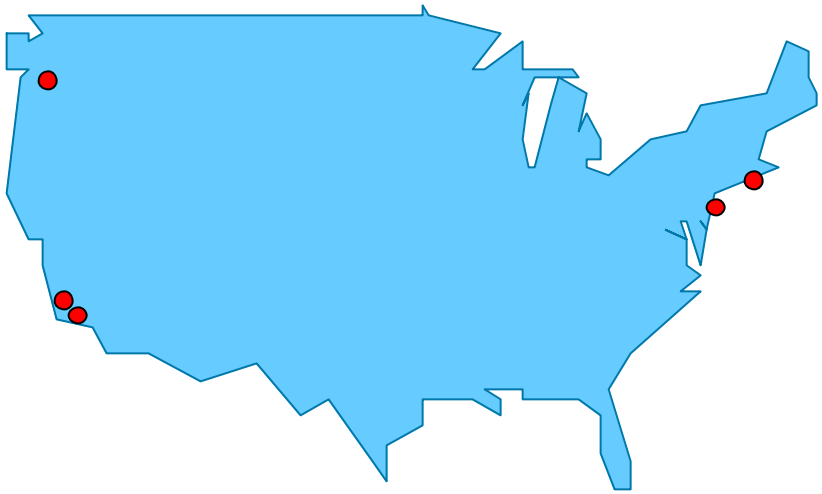
FC39715
R992909

HISTORICAL PERSPECTIVE

- U.S. EPA ORD funded initial activities
  - LFG/ADG
  - Gas survey
  - Preliminary economics
  - Development of gas cleanup technology
  - Internal F/C modifications
  - F/C demonstrations at landfills
  - ADG cleanup demonstration at WWT

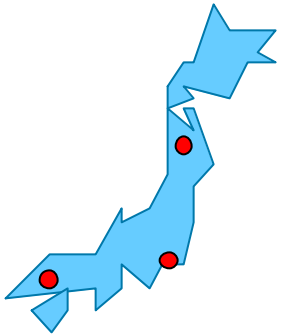
PC25 FUEL CELLS AT ADG FACILITIES

United States



Western Europe

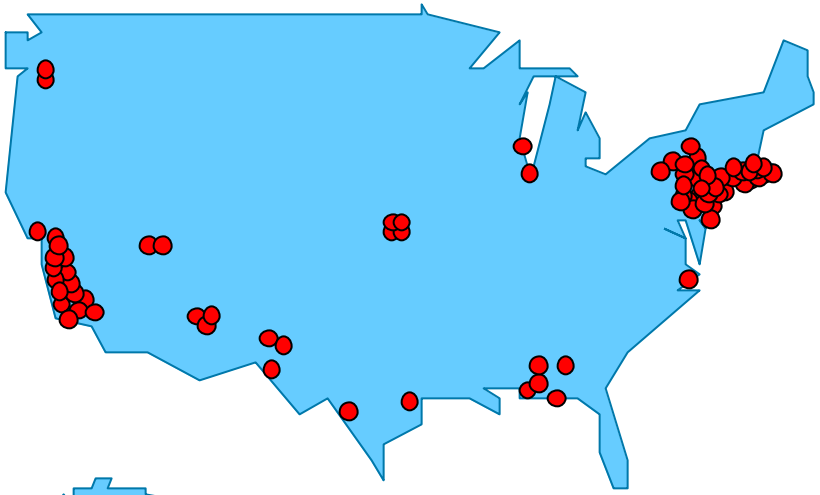
Japan

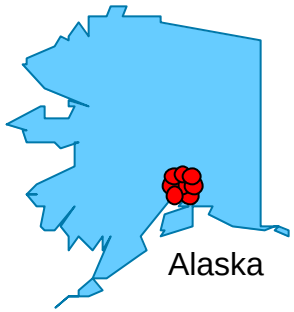


PPT-01847
R011106

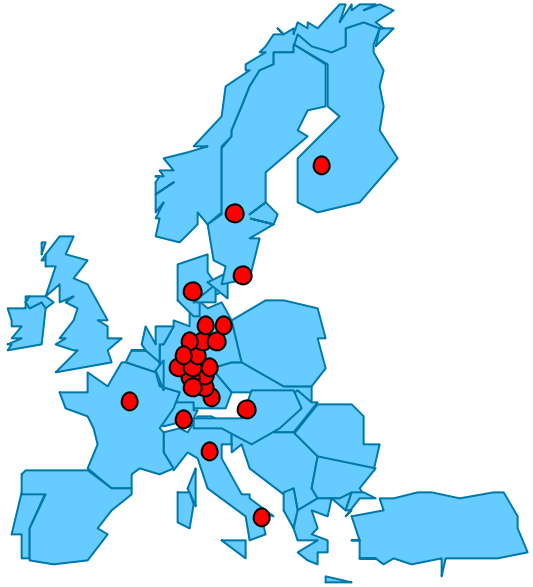
WORLDWIDE INSTALLATIONS

United States

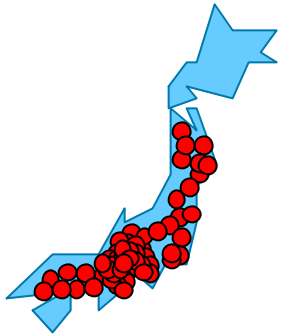




Western Europe



Japan



- **225 Units delivered**
- **Over 4 million operating hours**
- **Automatic control**
- **Remote monitoring**

CHARACTERISTICS OF ADG

- Major constituents
  - CH4/CO2
  - H2S
  - Trace organic halides
- Impact on fuel cell
  - CO2 increases system pressure drop
  - Sulfur & halides “ poison “ catalysts

PC25 MODIFICATIONS REQUIRED FOR ADG

- Larger fuel injector
  - Higher volumetric flow rate
- Larger piping
- Internal halide scrubber
- Software modifications
- External sulfur scrubber

YONKERS ADG SITE

- First fuel cell at U.S ADG site
  - NYPA/EPA/NYSERDA/EPRI
- Cleanup technology operated successfully
  - H2S removed on activated carbon
    - Sulfur deposition via claus reaction
  - Halides removed via conversion to a salt
    - Hydrogenation

YONKERS ADG FUEL CELL

- Unit in operation ~ 3 years
- Successful operation
- Operation provided valuable “lessons learned”
  - Implemented in future power plants/Installations

SUCCESSES

- PC25 can operate on ADG
- CO2 is an inert
- Sulfur removal system effective
  - Ambient pressure
  - Removes all H2S
  - Can be maintained while operating
- Halides system also effective
- Air emissions equivalent to natural gas

LESSONS LEARNED

- ADG is by product of WWT
- WWT operator is busy
- ADG is “wet”
- Sulfur in gas can vary
- ADG composition can vary
- ADG supply unreliable
- Fuel cell must accommodate
- Get “ buy in”
- Drain lines feeding F/C
- Monitor cleanup system
- Adjust power plant software
- Provide dual fuel capability

CONCLUSIONS

- ADG market is viable for PC25
  - Several in operation
- Cleanup technology works
- ADG supply unreliable
  - Accommodations necessary

WASTE WATER TREATMENT

1045-7

Yonkers, NY

USE OF ANAEROBIC DIGESTER GAS

Waste water treatment plant, Boston, Massachusetts

WCN-15800

ADG APPLICATION
Portland, Oregon

CA0469